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Genetic and Environmental Factors in Individual Differences of Cognitive Abilities in Primary School Children

Yulia Davydova[b], Victoria Ismatullina[a]*, Ivan Voronin[a], Ol'ga Ovcharova[a], Elena Sabirova[b], Sergey Malykh[a]

[a]*Psychological Institute of Russian Academy of Education, Moscow, Mokhovaya 9-4, 125009, Russia*
[b] *Kyrgyz-Russian Slavic University, Bishkek,Kievskaya str., 44, 720000, Kyrgyzstan*

Abstract

The study, based on a sample of Russian twins (34 pairs of monozygotic twins and 33 pairs of dizygotic twins aged 7-8 years), shows that genetic factors make a significant contribution to the development of individual differences in nonverbal intelligence. Eighty nine percents of phenotypic variance of nonverbal intelligence are explained by the genetic influences, while the contribution of non-shared environment explains the remaining 11%.

Keywords: heritability, environment, cognitive abilities, primary school age, nonverbal intelligence.

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1. Introduction

There are few such problems in behavioral genetics which attract such keen attention as the problem of genetic and environmental sources of individual differences in general cognitive ability (the g-factor), often called "intelligence" and measured by IQ tests. One could say that the behavioral genetics itself has emerged from the study of cognitive characteristics. F.Galton measured the intelligence (using the 18-items scale) in relatives of famous scientists, writers and politicians. As the results of his analysis have shown, the relatives of the prominent people, as a rule, were unusual persons themselves; the closer was the relative, the higher was the intellect [1]. The multitude of studies have been conducted since then, presenting evidence of the influence of genetic factors on the individual differences in intelligence, academic achievement, specific cognitive abilities, cognitive styles, etc. As estimated by T.Bouchard and M.McGue [2] on the basis of aggregate analysis of the results of studies with different kinds of relatives using structural equation modeling, the broad heritability of intelligence appeared to be 0.51, with the assortativity effects taken into account [3]. It is well known that heritability coefficients are

* Corresponding author. Tel.: +7-495-695-81-28; fax: +7-495-695-81-28
E-mail address: victoria2686@gmail.com

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culturally and sample-specific. These data were collected primarily in Europe and USA, while there are very few studies on the nature of individual differences in cognitive abilities conducted in Russia.
The aim of this article is to present the analysis of the role of genetic and environmental factors in individual differences of cognitive abilities in primary school children.

2. Study design and methods

Sixty-seven pairs of twins (34 monozygotic (MZ) and 33 dizygotic (DZ)) aged 7-8 years entered the study's sample. The twins' zygosity was assessed using a modified version of R.Nichols and W.Bilbro [4] questionnaire. The measure to assess the children's level of cognitive abilities was the J.Raven's [5,6] "Standard Progressive Matrices" (SRPM) test. The test was devised by its authors to assess the ability to perceive and derive the logical relations from the abstract verbal and nonverbal material. The SRPM test is now considered as a highly reliable and valid measure of abstract reasoning, namely – the g-factor or the general cognitive ability. The test consists of 60 multiple-choice tasks grouped in 5 sets (A to E) of 12 items each.
The contributions of genetic and environmental influences on individual differences in cognitive abilities were estimated using the structural equation modeling [7]. The data from MZ and DZ twins are used to estimate the contributions of the following components of phenotypic variance: additive (A) and non-additive (D) genetic factors, shared (C) and non-shared (E) environmental factors. The last component also includes the estimation of variance that comes from measurement error.

3. Results and discussion

3.1. Correlational analyses

The twin within-pair correlations are presented in the table 1. As shown in the table, the within-pair similarity of nonverbal intelligence level in MZ twins is relatively high (0.66-0.88), while the similarity of DZ twins is lower and varies from 0.45 to 0.62. According to these results, the genetic factors influence the individual differences of SRPM test scores.

3.2. Model-fitting analyses

As the model-fitting analyses have shown (see table 2), the full ACE model provided the best fit for the series A (A=0.15; C=0.56; E=0.29), D (A=0.60; C=0.06; E=0.33), E (A=0.53; C=0.22; E=0.25). The simple genetic AE model provided the best fit for the series B (A=0.79; E=0.21) and C (A=0.79; E=0.21) and for the overall score (A=0.89; E=0.11).
To conclude, the genetic component explains the largest part (89%) of variance in nonverbal intelligence in 7-8 years old children.
Let us describe the influences on components of nonverbal intelligence in detail. The largest contribution of genetic factors is found for the ability to find analogies between the pairs of figures by differentiating their elements (B series) - 79%, and the ability for the dynamic (fast) observation and following up the continuous

Table 1. Within-pair twin correlations for MZ and DZ twins

Series	MZ (N = 34)		DZ (N = 33)	
	r	Confidence interval	r	Confidence interval
A	0.749	0.550- 0.867	0.471	0.152-0.701
B	0.791	0.619 -0.891	0.448	0.124-0.686

C	0.808	0.639- 0.902	0.446	0.102-0.695
D	0.662	0.384- 0.830	0.507	0.173- 0.737
E	0.786	0.554-0.905	0.562	0.224-0.780
Overall score	0.883	0.761-0.945	0.620	0.328-0.804

change in objects (C series) - 79%, as well as the ability to find the quantitative and qualitative patterns of matrix construction as a whole and its rows and columns (D series) - 60%. The ability for the analysis-synthesis (E series) is equally influenced by the genetic (47%) an environmental (53%) factors. Meanwhile, the ability to differentiate the elements and find the links between the elements of gestalt, to fill in the missing part of the structure by comparing it to the example (A series) is influenced mostly by the common environmental (56%) and non-shared environmental (29%) factors.

Table 2. The results of model-fitting for nonverbal intelligence in 7-8 years old children

Series	The model	A	C	E
A	ACE	0.15 (0.00-0.79)	0.56 (0.00-0.80)	0.29 (0.17-0.47)
B	AE	0.79 (0.39-0.88)	-	0.21 (0.12-0.38)
C	AE	0.79 (0.26-0.88)	-	0.21 (0.12-0.36)
D	ACE	0.60 (0.00-0.82)	0.06 (0.00-0.63)	0.33 (0.18-0.60)
E	ACE	0.53 (0.00-0.86)	0.22 (0.00-0.73)	0.25 (0.14-0.47)
Overall score	AE	0.89 (0.41-0.94)	-	0.11 (0.06-0.21)

To conclude, the genetic component explains the largest part (89%) of variance in nonverbal intelligence in 7-8 years old children. Let us describe the influences on components of nonverbal intelligence in detail. The largest contribution of genetic factors is found for the ability to find analogies between the pairs of figures by differentiating their elements (B series) - 79%, and the ability for the dynamic (fast) observation and following up the continuous change in objects (C series) - 79%, as well as the ability to find the quantitative and qualitative patterns of matrix construction as a whole and its rows and columns (D series) - 60%. The ability for the analysis-synthesis (E series) is equally influenced by the genetic (47%) an environmental (53%) factors. Meanwhile, the ability to differentiate the elements and find the links between the elements of gestalt, to fill in the absent part of the structure by comparing it to the example (A series) is influenced mostly by the common environmental (56%) and non-shared environmental (29%) factors.

4. Conclusions

In overall, the study results provide evidence for the significance of genetic contribution (89%) for the phenotypic variance of nonverbal intelligence in primary school age. The non-shared environmental factors (the non-genetic influences that contribute to differences between relatives) seem to be the second most important for the individual differences in nonverbal intelligence in children.

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